DOE NASA CONTRACTOR REPORT

DOE NASA CR-150620

PRELIMINARY DESIGN PACKAGE FOR MAXI-THERM HEAT EXCHANGER MODULE

Prepared from documents provided by

Sigma Research, Inc.
2952 George Washington Way
Richland, Washington 99352

Under Contract NAS8-32260 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy

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This work was done under the technical management of Mr. James D. Hankins, George C. Marshall Space Flight Center, Alabama.

16. ABSTRACT

Sigma Research, Inc., has contracted to develop three identical heat exchangers for use in a solar heating and cooling system installed in a single-family dwelling. Each exchanger consists of one heating and cooling module and one submersed electric water heating element.

This report contains the necessary information to evaluate the preliminary design of the Maxi-Therm heat exchanger. It is a compilation of the following documents: Development Plan, Verification Plan, Performance Specification, Special Handling, Installation and Maintenance Tools List, Subsystem Hazard Analysis and Proposed Data for Prototype Design Review.

For final design and installation procedures, see DOE/NASA documents CR-150512 and CR-150516.

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1-1 Development Plan

The development plan defines the objectives of this program and the methods used in achieving these objectives.

1-1.1 Overall Program Objectives

The goal of the overall development program is to permit the optimization of the heating module such that, when brought to market, it possesses the best combination of performance, consumer appeal, and component manufacturing. To insure success, this program must be supported by subprograms which include certification, verification, and quality assurance. In the following sections, the major tasks within the development program are detailed, with Figure 1-1.1 containing a program schedule for the five development tasks.

1-1.2 Task 1: Thermal/Cost Performance of Alternate Exchanger Elements and Reorientation of Exchanger Module

The reorientation of the heat rejection portion of the exchanger module to a horizontal position, as opposed to the vertical position utilized in the initial prototype S-101-P3, will allow a reduction in package size, simplification of the shut-off valving, and better adaptability to a wide range of storage tank sizes. In addition, the incorporation of 1-5/8-inch O.D. copper heat exchanger tubes with aluminum fins will permit a reduction in module weight, with a subsystem cost reduction and performance improvement also appearing possible through the use of these elements. This unit will be designated by Model Number S-101-P4. Plenum, water lines, and tube sheets in this unit will be brass.

1-1.3 Task 2: Low Pressure Fluid Valve

A reliable, economical valve shall be defined for the purpose of curtailing heat rejection from the exchanger. This will involve the investigation of both water and air shut-off valves to determine the preferable mode of control,

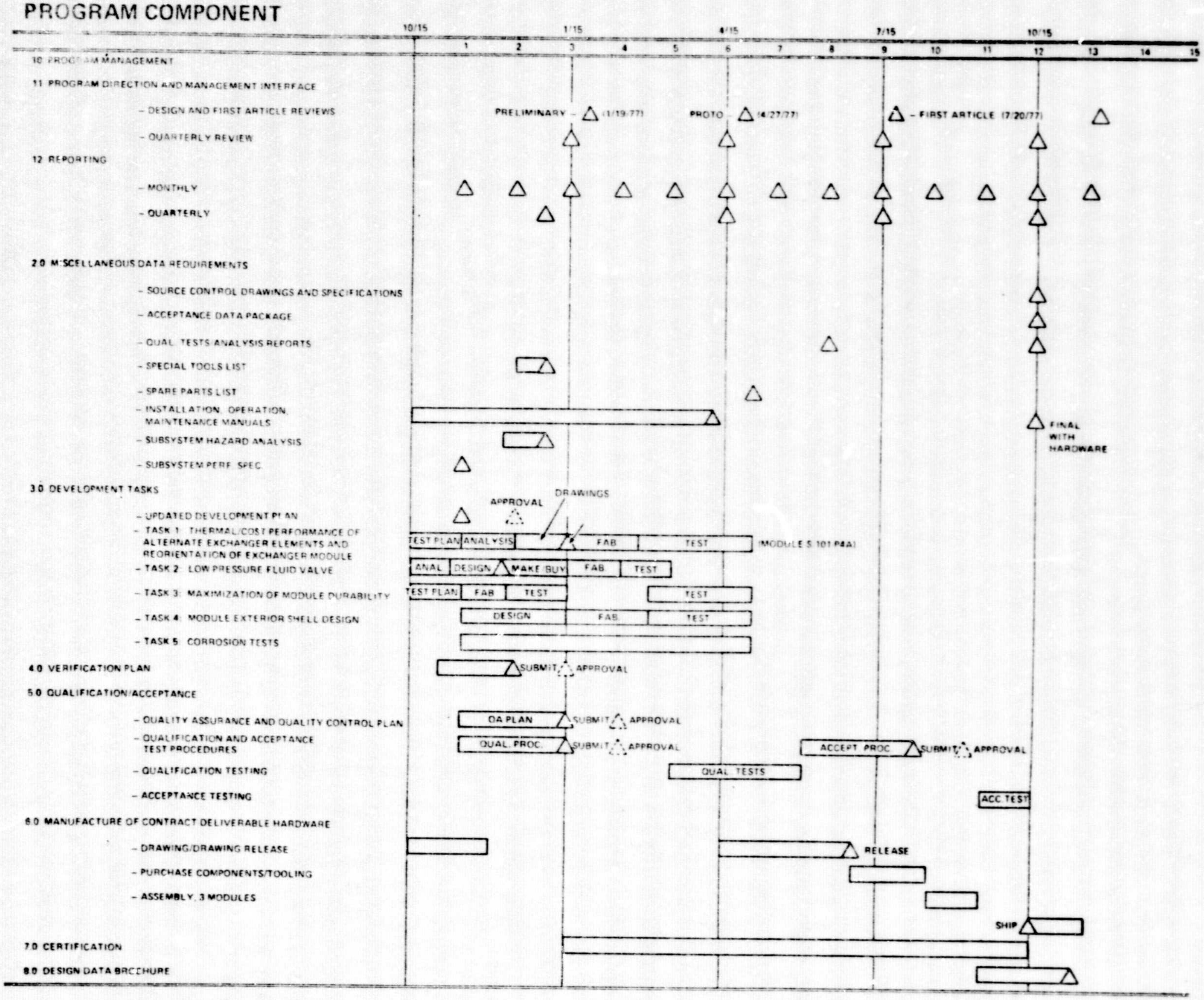

Figure 1-1.1. Program Schedule for Solar Heating and Cooling Module with Supplementary Heating (for use in Single Family Buildings)

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since curtailment of either flow will cause water-side thermosyphon operation to cease. Initial phases of this task will define the mode of control and determine whether to make or buy the resulting unit. The valve design settled upon will be subsequently tested as a component and in conjunction with the operationg subsystem.

1-1.4 Task 3: Maximization of Module Durability

On the basis of structural analyses and empirical tests, subsystem ruggedness will be maximized. Anticipated areas of emphasis include frame rigidity and leak-tightness of various soldered and/or welded joints.

1-1.5 Task 4: Module Exterior Shell Design

Consumer acceptance of new products can be influenced significantly by product appearance. In this task, methods of forming an aesthetically appealing exterior will be examined. The exterior shell design will be incorporated into the prototype test model, S-101-P4A.

1-1.6 Task 5: Corrosion Tests

Corrosion of the interior portions of the heat exchanger will be investigated in a testing program to assure maximum module longevity. Typical dissimilar metal joints which may exist within the prototype or deliverable units will be fabricated and exposed to ambient conditions of the type existing in actual service.

1-2 Verification Plan

The verification plan defines the method by which each of the requirements during the development, qualification, and acceptance phases will be accomplished. For requirements in which the performance mode is experimental, further amplification is included. To permit an overview of the areas of investigation and the performance mode, Table 1-2.1, the Verification Cross Reference Matrix, is included.

1-2.1 Verification Testing - Hardware

The tools and related equipment necessary to carry out the various phases of the verification testing are available at Sigma Research, Inc. In Table 1-2.2, these tools are listed categorically by their primary function within the various phases of the verification program. All maintenance on equipment is performed in-house at Sigma Research or by authorized agents of the supplier to insure proper operation and accuracy.

1-2.2 Verification Testing - Scheduling

The scheduling of verification test phases is designed to permit the identification and correction of potential problem areas at an early stage of the program such that all tasks are completed within the performance period of the contract. The schedule for these various test phases is given in Figure 1-2.1.

1-2.3 Verification Testing Levels and Rationale

The verification tests, in general, are designed to both evaluate the thermal performance of the Maxi-therm modules, as well as assess their integrity and operability. In the case of thermal performance, this will involve operation of the Maxi-therm modules over the water temperature range of 86°F (30°C) to 194°F (90°C) with a minimum of three complete test sequences being deemed necessary to verify performance and assure data repeatibility. The temperature span so specified

TABLE 1-2.1

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ITEM (NAME & PART NO.) Heating and Cooling Sub-System, Model No. S-101	VERIFICATION CROSS REFERENCE MATRIX			
VERIFICATION METHOD:	1. SIMILARITY 2. ANALYSIS	3. INSPECTION 4. TEST	N/A NOT APPLICABLE	
PERFORMANCE REQUIREMENT	VERIFICATION PHASE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
Subsystem Specification				
Heating	2, 4	4	3, 4	
Relative Humidity	4	4	4	
Design Parameters	4	4	4	
Interim Performance Criteria				
1.8 Auxiliary Energy	3	3	3	Vendor-supplied heating element
2.2 Mechanical Stresses	2, 4	4	3	
2.3 Leakage Prevention	3, 4	3, 4	3, 4	Bubble pressurization test
2.3.2 Pressure Test	2, 4	2, 4	4	
2.3.3 Air Handling	2, 3, 4	3, 4	3, 4	Fan/motor assembly
2.8.1 Vent	3	3	3	
3.1 Structural Design Basis	2, 4	3	3	
3.1.1 Applic. Standards	2, 4	3	3	
3.1.2 Service Loads	2, 4	4	3	
3.2 Load Capacity	2, 4	4	3	
3.3.1 Damage Resistance	4	4	3	
4.1.2 Electrical Codes	3	3	3	Relays, solenoids
4.7.1 Protection from Heated Components	4	3	3	Shroud
5.2.1 Thermal Degradation	4	4	3	Corrosion products
5.2.4 Leakage	4	4	4	Pressurization test
5.2.5 Deterioration of gaskets and sealants	4	3	3	Hose couplings to storage tank
5.3 Compatibility	4	3	3	
6.1 Accessibility for Maintenance	2, 3, 4	3	3	
6.1.5 Filters	2, 3, 4	3, 4	3	Air Filter

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TABLE 1-2.1 (Continued)

PF01-358c

ITEM (NAME & PART NO.)
Heating and Cooling Subsystem, Model No. S-101

VERIFICATION CROSS REFERENCE MATRIX

VERIFICATION METHOD: 1. SIMILARITY 2. ANALYSIS 3. INSPECTION 4. TEST N/A NOT APPLICABLE

PERFORMANCE REQUIREMENT	VERIFICATION PHASE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
6.2 Manuals	3	3	3	
6.2.4 Replacement Parts	3	3	3	

TABLE 1-2.2. TEST HARDWARE

Purpose	Hardware
1. Temperature Measurement	Doric Model 220 Automatic Data Acquisition System with .1°C Resolution
	Doric Digitrend Model DS-350 with .1°C Resolution
2. Static and Dynamic Air Measurements	Coaxial Pitot Tube
	Inclined Manometer
	Psychrometer
3. Preparation and Examination of Metallographic Samples	Leitz-Ortholux Metallographic Microscope with Nikon EFM Automatic Photomicroscopy System
	Vibromet Polisher
	Ohaus Triple Beam Balance - 2.6 kg Capacity
	Christian Becker Analytic Balance - 200 gm Capacity
	Cole-Parmer Ultrasonic Cleaner - 1 Quart Capacity
	Lab-Con-Co Fume Hood
	Craftsman Vibrating Scribe with Carbide Tip
4. Electrical Supply, Monitoring, and Inspection	Fluke Digital Voltmeter Model 8000A
	EICO Model 460 Oscilloscope
	Hewlett-Packard Power Supply Model 6438B
	Variac - 20 amp
5. Metrology	3 ft x 7 ft Standridge Granite Surface Plate
	18-in. Brown & Sharpe Hite-icator
	18-in. Kanon Height Gage
	8-in. x 10-in. Precision Angle Plates
	1-in. to 6-in. Micrometers
	Helios Vernier Caliper - 6 in. Capacity
	Ames Dial Micrometer with Ground Surface Plate

TABLE 1-2.2 (Continued)

Purpose	Hardware
6. Leak Testing	Welch Duo-Seal Model 1402 Vacuum Pump
	Nitrogen Bottles, Regulators, and Gages
	10-ft x 10-ft x 10-ft Water-filled Submersion Tank
7. Data Interpretation and Reduction	Hewlett-Packard HP-65 Programmable Calculator
	Texas Instruments Model 733ASR Printing Terminal with Dual Tape Drive
8. Stress Loading	Dillon Dynamometer - 10,000 lb Capacity

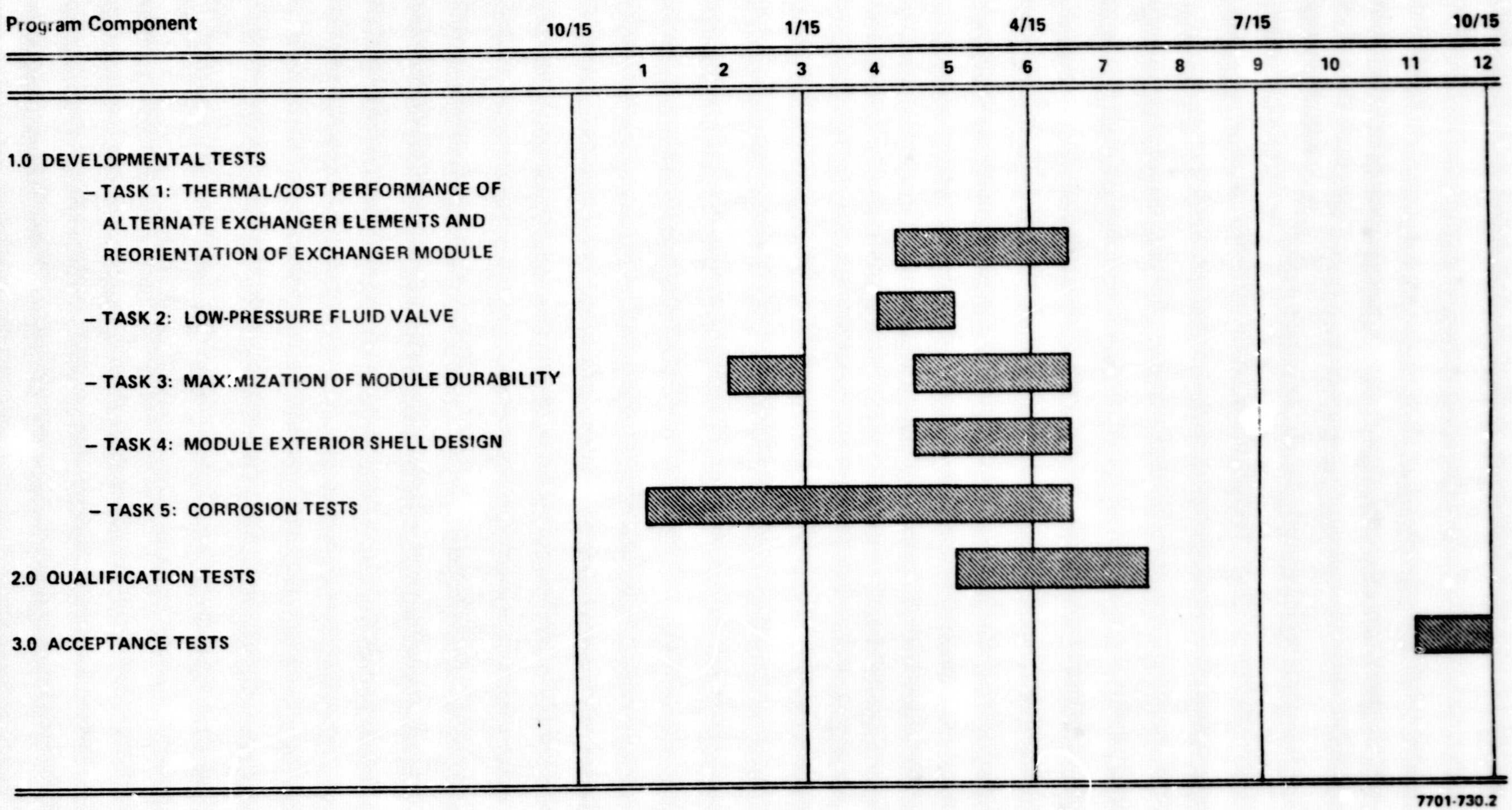

Figure 1-2.1. Testing Schedule For Prototype Unit S-101-P4A and Finished Units S-101.

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is expected to be in excess of that realized in an actual installation and will thus insure the exclusion of any unforeseen performance anomalies. In addition, operation in excess of those temperatures encountered in actual practice will help to assure the module's integrity under lower-level thermal stress loadings. Inlet air temperatures, being somewhat variable within the test area, will be maintained within the range of 65°F to 75°F (18.3°C to 23.9°C) during tests.

To insure the modules integrity under static loading as well as the stresses and impact loadings common to transit and installation, key solder, braze, and weld joints will be examined to determine possible failure modes. Where necessary, the designated joints, or duplicates thereof, will be subjected to stress loadings designed to duplicate those anticipated. When possible, these tests will continue to failure to permit an estimation of the factors of safety for the joints. In each case, three test samples will be utilized to insure accurate evaluation and repeatibility.

Also related to the integrity of the module, and occurring due to lack of same, is the leakage of working fluid. In both the prototype and deliverable modules, leakage tests will be performed following fabrication and will involve total submersion of the sealed exchanger in water, followed by internal pressurization (16 psia min) with nitrogen or argon gas. Leakage will then be determined by the presence of bubbles emanating from the exchanger. Further leakage tests during major thermal test sequences will involve visual examination at maximum operating temperature (194°F) to determine thermal stress-induced leakage paths. Dissimilar metal joints subject to corrosion action will also be examined for possible leakage and, in addition, test capsules containing samples having dissimilar metal joints of the type utilized in the modules will be prepared. The operating temperature

level of these capsules will be not less than 140°F. The use of these capsules will permit corrosion evaluation under controlled conditions and over extended time periods at elevated temperatures.

Proper operation of the module components, including the thermal shut-off valve and electrical system, will be assured through utilization of the specified components during thermal test sequences. In addition, separate on-off operating tests for the valve are anticipated to fully assess performance. A minimum of 100 such cycles is deemed necessary for confirmation of proper operations. In the case of the electrical system, additional examination and circuitry testing is required to insure proper installation and minimize shock hazards.

In addition to these major components, a number of other module components such as the exterior shell, filters, inlet and outlet vents, etc. will be a part of the prototype and deliverable modules during thermal testing and will be evaluated at that time. Areas of examination will include vibration, stress-induced distortion, and general operability.

1-4 Subsystem Performance Specification

The Subsystem Performance Specification establishes the requirements for the design, performance and installation of the thermosyphon heat exchanger and auxiliary heating element subsystem Model S-101 for use in solar heating applications. In addition, it designates the applicable Interim Performance Criteria for the subsystem.

1-4.1 Subsystem Performance

The performance rating points for the Maxi-therm Model S-101 are defined in Table 1-4.1 for the conditions of 140°F inlet water temperature and 70°F inlet air. Also included, in Figure 1-4.1, are the predicted thermal operating characteristics of the subsystem. The rating points given in Table 1-4.1 are likewise included in this figure, with the remaining portions of the curves being for reference only and not considered a part of the Subsystem Performance Specification.

1-4.2 Interim Performance Criteria

Table 1-4.2 includes the paragraph numbers and titles of the Interim Performance Criteria(1) for heating, heating and cooling, and hot water solar subsystems. The paragraphs applicable to the Maxi-therm Model S-101 are designated by a solid dot (•) following the paragraph title.

1-4.3 Installation Drawings

Installation drawings to be included when completed.

TABLE 1-4.1

SUBSYSTEM PERFORMANCE SPECIFICATION - MODEL S-101

Subsystem Identification

This table defines the performance and specifications for (Single Family Residence), (Sigma Research, Inc.), Subsystem Model Number (S-101).

Specification

The total heating capacity shall be no less than 54,000 BTU/Hr at 1640 CFM of air flow entering at 70°F dry bulb and 58°F wet bulb (50% relative humidity) and leaving at no greater than 105°F dry bulb. Exposed heated panel (baseboard or ceiling) temperature shall not exceed 105°F heating capacity evaluated at storage tank mean temperature of 140°F. For a 20 percent ethylene glycol mixture, total heating capacity is reduced to 50,900 BTU/Hr. The furnished auxiliary electric water heating element shall have a heating capacity of 65,000 BTU/Hr.

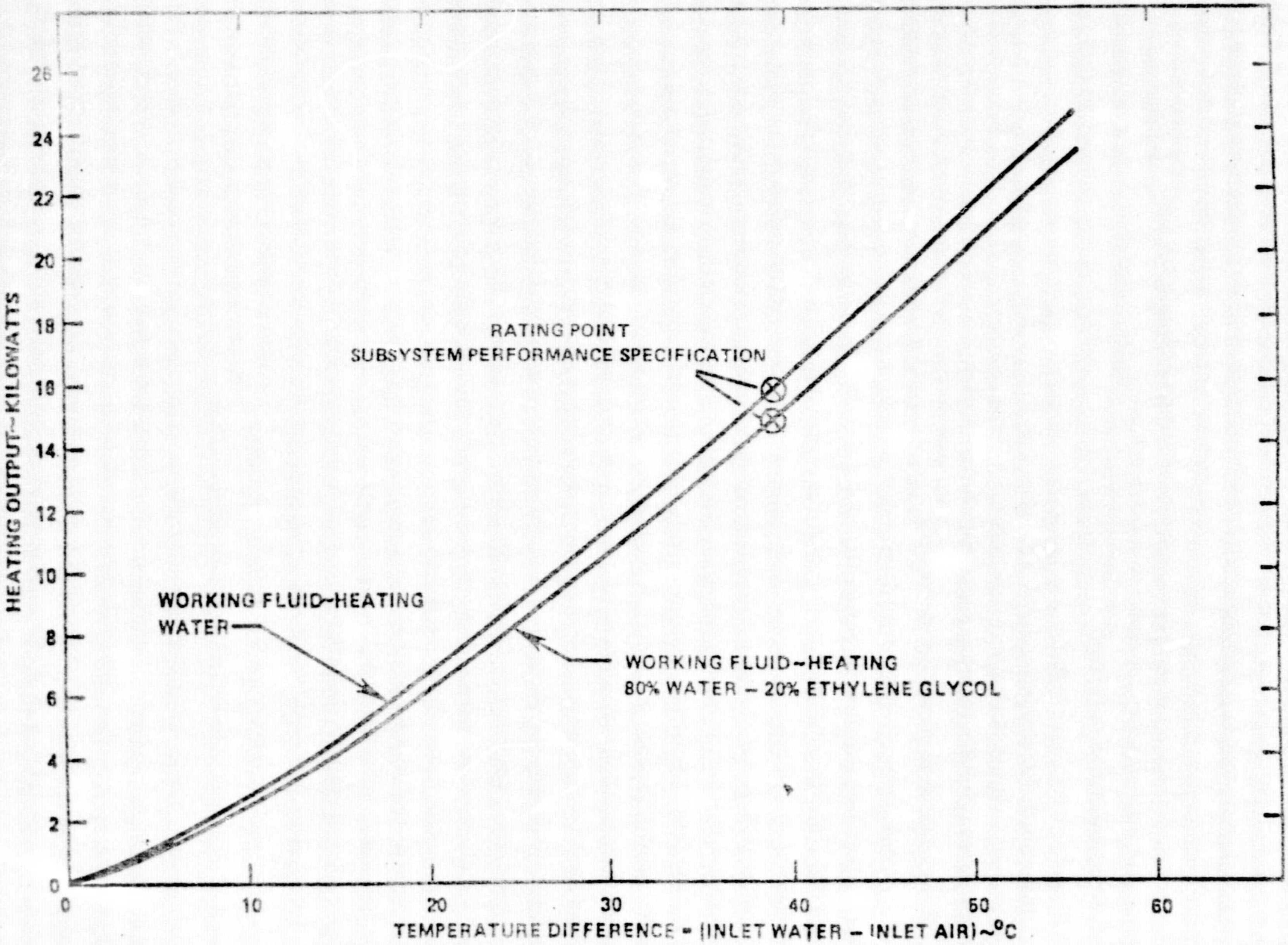

FIGURE 1–4.1. PREDICTED OPERATING CHARACTERISTICS OF MAXI-THERM MODEL S-101. POINTS DENOTED ARE THE SUBSYSTEM PERFORMANCE SPECIFICATION RATING POINTS. REMAINING PORTIONS OF LINES ARE NOT CONSIDERED A PART OF THE PERFORMANCE SPECIFICATION.

TABLE 1-4.2

SPECIFICATION NO. ____________
REVISION ____________
DATE ____________

RESIDENTIAL SUBSYSTEMS. INTERIM PERFORMANCE CRITERIA SUMMARY

SHEET 1 OF 6

SUBSYSTEM APPLICATION

A – APPLICABLE TO TYPE SYSTEMS INDICATED

NA – NOT APPLICABLE

TYPE SYSTEMS

H – HEATING

HC – HEATING AND COOLING

HW – HOT WATER

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEMS		
	H	HC	HW
1.1 H and HC Performance ●	A	A	
1.1.1 Heating Design Temperatures ●	A	A	
1.1.2 Cooling Design Temperatures	NA	A	
1.1.3 Relative Humidity and Water Vapor Pressure ●	A	A	
1.1.4 Solar Contribution	NA	NA	
1.1.5 Operation Impairment ●	A	A	
1.2 HW System/Subsystem Performance	NA	NA	
1.2.1 Water Design Temperature	NA	NA	
1.2.2 Storage Design Capacity	NA	NA	
1.2.3 Solar Contribution	NA	NA	
1.2.4 Operational Impairment	NA	NA	
1.3 Collector Performance	NA	NA	

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEMS		
	H	HC	HW
1.3.1 Collector Efficiency	NA	NA	A
1.4 Thermal Storage	A	A	A
1.4.1 Storage Capacity	A	A	A
1.5 Habitability of Occupied Spaces	A	A	
1.5.1 Heat or Humidity Transfer Effects	A	A	
1.6 Energy Transport Efficiency ●	A	A	
1.6.1 Thermal Losses and Electrical Power ●	A	A	
1.7 Control ●	A	A	
1.7.1 Installation and Maintenance ●	A	A	
1.7.2 Manual Adjustment	A	A	
1.7.3 Inhabited Space Temperature	NA	NA	
1.7.4 Hot Water Temperature	NA	NA	
1.8 Auxiliary Energy ●	A	A	
1.8.1 Design Loads ●	A	A	

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TABLE 1-4.2 (Continued)

SPECIFICATION NO ________
REVISION ________
DATE ________

RESIDENTIAL SUBSYSTEMS, INTERIM PERFORMANCE CRITERIA SUMMARY

SHEET 2 OF 6

SUBSYSTEM APPLICATION

A – APPLICABLE TO TYPE SYSTEMS INDICATED

NA – NOT APPLICABLE

TYPE SYSTEMS

H – HEATING

HC – HEATING AND COOLING

HW – HOT WATER

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEMS		
	H	HC	HW
2.1 System Design Conditions ●	A	A	
2.1.1 Equipment Capabilities ●	A	A	
2.1.2 Noise or Erosion - Corrosion ●	A	A	
2.1.3 Operating Conditions ●	A	A	
2.1.4 Fluid Flow in Collectors	A	A	
2.1.5 Entrapped Air	A	A	
2.1.6 Thermal Expansion of Fluids	A	A	
2.1.7 Pressure Drops ●	A	A	
2.1.8 Condensate Removal	A	A	
2.2 Mechanical Stresses ●	A	A	
2.2.1 Vibration Stress Levels	A	A	
2.2.2 Vibration from Moving Parts	A	A	
2.2.3 Water Hammer	NA	NA	
2.2.4 Vacuum Relief Protection	A	A	
2.2.5 Thermal Changes	A	A	
2.2.6 Flexible Joints	A	A	
2.3 Leakage Prevention ●	A	A	

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEMS		
	H	HC	HW
2.3.1 Pressure Test: Nonpotable Fluids ●	A	A	A
2.3.2 Pressure Test: Potable Water	A	A	A
2.3.3 Air Transport Systems ●	A	A	
2.4 Collector Adjustment	NA	NA	
2.4.1 Orientation and Tilt	NA	NA	
2.4.2 Mutual Shadowing	NA	NA	
2.5 Subsystem Isolation	NA	NA	
2.5.1 Shutdown in Multifamily Housing	NA	NA	
2.6 Heat Transfer Fluid Quality			
2.6.1 Liquid Quality			
2.6.2 Air Quality			
2.6.3 Fluid Quality			
2.6.4 Freezing Protection			
2.7 Piping Supports			
2.7.1 Applicable Plumbing Standards	A	A	
2.8 Excessive Pressure and Temperature Protection ●	A	A	
2.8.1 Relief Valves and Vents ●	A	A	
3.1 Structural Design Basis ●	A	A	

TABLE 1-4.2 (Continued)

SPECIFICATION NO. ________
REVISION ________
DATE ________

RESIDENTIAL SUBSYSTEMS. INTERIM PERFORMANCE CRITERIA SUMMARY

SHEET 3 OF 6

SUBSYSTEM APPLICATION

A – APPLICABLE TO TYPE SYSTEMS INDICATED

NA – NOT APPLICABLE

TYPE SYSTEMS

H - HEATING

HC - HEATING AND COOLING

HW - HOT WATER

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEMS H	HC	HW	RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEMS H	HC	HW
3.1.1 Applicable Standards ●	A	A		3.8.1 Foundation Settlement	A	A	A
3.1.2 Service Loads ●	A	A		3.9 Ponding Condition	NA	NA	
3.2 Failure Loads and Load Capacity ●	A	A		3.9.1 Design Provisions	NA	NA	
3.2.1 Ultimate Load Combinations	A	A		4.1 Plumbing and Electrical Installation	A	A	
3.2.2 Ice Loads	NA	NA		4.1.1 Plumbing Codes	A	A	
3.2.3 Vehicular Loads	NA	NA		4.1.2 Electrical Codes ●	A	A	
3.2.4 Load Capacity	NA	NA		4.2 Fail-Safe Controls	A	A	
3.3 Damage Control	A	A		4.2.1 System Failure Prevention	A	A	
3.3.1 Resistance to Damage ●	A	A		4.2.2 Automatic Pressure Relief Valves	A	A	
3.3.2 Glazing Design	NA	NA		4.3 Fire Safety	A	A	
3.4 Cyclic Loads	A	A		4.3.1 Applicable Fire Standards	A	A	
3.4.1 Deflection Limitations	A	A		4.3.2 Penetrations through Fire Rated Assemblies	NA	NA	
3.5 Cutting of Structural Elements	NA	NA		4.4 Toxic	A	A	
3.5.1 Design Provisions	NA	NA		4.4.1 Provisions of Catch Basins	A	A	
3.6 Creep and Residual Deflection	NA	NA		4.4.2 Detection of Toxic and Flammable Fluids	NA	NA	
3.6.1 Deflection Limitations	NA	NA		4.5 Safety	NA	NA	
3.7 Hail Resistance	NA	NA		4.5.1 Emergency Egress and Access	NA	NA	
3.7.1 Hail Size and Loading	NA	NA		4.5.2 Identification and Location of Controls	A	A	
3.8 Constraint Loads	A	A					

TABLE 1-4.2 (Continued)

SPECIFICATION NO ______
REVISION ______
DATE ______

RESIDENTIAL SUBSYSTEMS, INTERIM PERFORMANCE CRITERIA SUMMARY

SHEET 4 OF 6

SUBSYSTEM APPLICATION

A - APPLICABLE TO TYPE SYSTEMS INDICATED

NA - NOT APPLICABLE

TYPE SYSTEMS

H HEATING

HC HEATING AND COOLING

HW HOT WATER

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEMS H	HC	HW	RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEMS H	HC	HW
4.6 Protection of Potable Water & Circulated Air	A	A		5.2.3 Thermal Cycling Stresses	A	A	
4.6.1 Contamination by Materials	A	A		5.2.4 Leakage ●	A	A	
4.6.2 Separation of Circulation Loops	A	A		5.2.5 Deterioration of Gaskets and Sealants ●	A	A	
4.6.3 Backflow Prevention	A	A		5.2.6 Transmission Losses Due to Outgassing	A	A	
4.6.4 Growth of Fungi	A	A		5.3 Chemical Compatibility of Components ●	A	A	
4.7 Excessive Surface Temperatures	A	A		5.3.1 Materials/Transfer Fluid Compatibility ●	A	A	
4.7.1 Protection from Heated Components ●	A	A		5.3.2 Corrosion of Dissimilar Materials ●	A	A	
5.1 Effects of External Environment	A	A		5.3.3 Corrosion by Leachable Substance	A	A	
5.1.1 Solar Degradation	NA	NA		5.3.4 Effects of Decomposition Products ●	A	A	
5.1.2 Soil Corrosion	NA	NA		5.4 Components Involving Moving Parts	A	A	
5.1.3 Airborne Pollutants	A	A		5.4.1 Wear and Fatigue	A	A	
5.1.4 Dirt Retention on Cover Plate Surface	NA	NA		6.1 Accessibility for Maintenance ●	A	A	
5.1.5 Abrasive Wear	NA	NA		6.1.1 Access for System Maintenance ●	A	A	
5.1.6 Fluttering by Wind	NA	NA		6.1.2 Access for System Monitoring ●	A	A	
5.2 Temperature & Pressure Resistance	A	A		6.1.3 Draining and Filling of Liquids ●	A	A	
5.2.1 Thermal Degradation ●	A	A		6.1.4 Flushing of Liquids Subsystems ●	A	A	
5.2.2 Deterioration of Heat Transfer Fluids	A	A					

TABLE 1-4.2 (Continued)

SPECIFICATION NO. ______
REVISION ______
DATE ______

RESIDENTIAL SUBSYSTEMS, INTERIM PERFORMANCE CRITERIA SUMMARY

SHEET 5 OF 6

SUBSYSTEM APPLICATION

A – APPLICABLE TO TYPE SYSTEMS INDICATED

NA – NOT APPLICABLE

TYPE SYSTEMS

H – HEATING

HC – HEATING AND COOLING

HW – HOT WATER

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEMS		
	H	HC	HW
6.1.5 Filters ●	A	A	
6.1.6 Potable Water Shutoff	NA	NA	
6.2 Installation, Operation and Maintenance Manual ●	A	A	
6.2.1 Installation Instructions ●	A	A	
6.2.2 Maintenance and Operation Instructions ●	A	A	
6.2.3 Maintenance Plan ●	A	A	
6.2.4 Replacement Parts ●	A	A	
6.3 Repair and Service Personnel ●	A	A	
6.3.1 Maintenance of H and HC Systems ●	A	A	
6.3.2 Maintenance of DHW System	NA	NA	
7.1 Design	NA	NA	
7.1.1 Dwelling Design	NA	NA	
7.1.2 Mobile Home Design	NA	NA	
7.1.3 Site Design	NA	NA	
7.1.4 Passive Use of Solar Energy	NA	NA	
7.2 Adequate Space	NA	NA	
7.2.1 Collector Area	NA	NA	

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEMS		
	H	HC	HW
7.2.2 Storage Area	NA	NA	
7.2.3 Utility Chases	NA	NA	
7.3 Functioning of Dwelling Site	NA	NA	
7.3.1 Space Use	NA	NA	
7.3.2 Shading of Adjacent Structures	NA	NA	
7.3.3 Impace of Environment	NA	NA	
7.3.4 View	NA	NA	
8.1 Interference with Mechanical Operation	NA	NA	
8.1.1 Blockage of Solar Subsystem	NA	NA	
8.1.2 Shading of Collector	NA	NA	
8.1.3 Sensor Location	NA	NA	
8.2 Mechanical & Electrical Functioning of Dwelling and Site	NA	NA	
8.2.1 Exhaust and Venting	NA	NA	
8.2.2 Utilities	NA	NA	
8.3 Mechanical & Electrical Functioning of Connections	NA	NA	
8.3.1 Plumbing Connections	NA	NA	

TABLE 1-4.2 (Continued)

SPECIFICATION NO. ____________
REVISION ____________
DATE ____________

RESIDENTIAL SUBSYSTEMS. INTERIM PERFORMANCE CRITERIA SUMMARY

SHEET 6 OF 6

SUBSYSTEM APPLICATION

A - APPLICABLE TO TYPE SYSTEMS INDICATED

NA - NOT APPLICABLE

TYPE SYSTEMS

H - HEATING

HC - HEATING AND COOLING

HW - HOT WATER

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEMS		
	H	HC	HW
8.3.2 Electrical Connections	NA	NA	
9.1 Structural Integrity	NA	NA	
9.1.1 Movements in Adjacent Structures	NA	NA	
9.2 Structural Integrity of Dwelling	NA	NA	
9.2.1 Loads	NA	NA	
9.2.2 Penetration of Structural Members	NA	NA	
9.3 Structural Connections	NA	NA	
9.3.1 Structural Connections	NA	NA	
9.3.2 Brittle Subsystem	NA	NA	
9.3.3 Strength and Stiffness	NA	NA	
10.1 Safety of Dwelling and Site	NA	NA	
10.1.1 Fire	NA	NA	
10.1.2 Accidents	NA	NA	
11.1 Durability	NA	NA	
11.1.1 Vegetation	NA	NA	
11.2 Durability and Reliability of Dwelling and Site	NA	NA	
11.2.1 Chemical Corrosion	A	A	

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEMS		
	H	HC	HW
11.2.2 Heat and Moisture	A	A	
11.2.3 Exterior Penetrations	NA	NA	
11.3 Durability and Reliability of Connections	NA	NA	
11.3.1 Material Compatibility	A	A	
12.1 Maintainability of H, HC, HW Systems	NA	NA	
12.1.1 Accessibility	NA	NA	
12.1.2 Misuse	NA	NA	
12.1.3 Permanent Maintainance Accessories	NA	NA	
12.2 Maintainability of Dwelling and Site	NA	NA	
12.2.1 Accessibility	NA	NA	
12.2.2 Ice Dams	NA	NA	
12.3 Connections	NA	NA	
12.3.1 Accessibility	NA	NA	
13.1 Visual Characteristics of Dwelling and Site	NA	NA	
13.1.1 Dwelling	NA	NA	
13.1.2 Neighborhood	NA	NA	

REFERENCES - SECTION 1-4

1. Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings, January 1, 1975, U. S. Department of Housing and Urban Development.

3-15 Special Handling, Installation, and Maintenance Tools List

The tools required for installation and general maintenance consist of those generally found in a home workshop, such as wrenches, pliers, screwdrivers, electric drill, etc. and, as such, do not constitute "special" tools. Handling of the module or, more specifically, transit, delivery and positioning within the residence requires the type of equipment (dolly, hand truck, etc.) common to home appliance handling and are not considered "special" tools. For major operations such as the disassembly and repair of the fan drive electric motor, it is assumed that the consumer will employ a local service and repair shop which is knowledgeable in, and equipped to perform, these services. In these instances, the use of standard off-the-shelf components for the electrical relay, electric motor, 115 VAC to 24 VAC step-down transformer, etc. permits ready repair and/or replacement by these firms.

3-18 Subsystem Hazard Analysis

In general, the simplicity of construction and operation in the Maxi-therm subsystem eliminates the potential hazards found in conventional residential heating systems (i.e. explosion and leakage of toxic substances). The only potential hazard foreseen in the Maxi-therm subsystem would involve the electrical circuitry and components. Should an individual contact the 115 VAC connections in the subsystem or, in the event of a short circuit occurring due to component failure or water influx, the outer shell, a potentially lethal electrical shock could result. The first mode of short circuiting could result from deterioration of electrical insulation or abnormal component abuse, with the second occurring due to working fluid leakage or flooding of the residence.

The design steps taken to eliminate these hazards consist of the following:

1. Direct contact with "hot" electrical leads. Electrical connections and the major portion of the circuitry for the electrical components will be located within the outer shell of the module and will conform to MPS (4900.1)[1] where applicable. In addition, a number of the components, such as the blower drive motor, electrical relay, and step-down transformer will be within this enclosure, with access openings in the outer shell leading to electrical junctions or components being identified with warning signs. Electrical leads supplying power to the module will be encased within conduit, which will couple directly to the outer shell and thus eliminate shock hazards exterior to the outer shell. Electrical leads connecting to the auxiliary tank heaters will be encased in a similar manner up to the heater elements. Since the length and routing of

electrical leads and conduit will most likely be unique for each installation, they are not supplied with the Maxi-therm subsystem, although provision for their connection will be incorporated into the unit.

2. Short circuiting due to component failure or water influx. To eliminate shock hazards in the event of short circuiting, provision will be made for the residence electrical ground circuit to be attached to the frame and outer shell. In addition, the entry of water into electrical components in the event of working fluid leakage will be minimized through careful specification of mounting position. Drain holes will also be incorporated into the lower portions of the shell to preclude working fluid entrapment in the event of a system leak. Should flooding of the residence occur, it is recommended that disassembly and inspection of the electrical components be performed prior to system use.

REFERENCES - SECTION 3-18

1. HUD Minimum Property Standards, One and Two Family Dwellings (No. 4900.1), U. S. Department of Housing and Urban Development, Washington, D. C. (1973, Revised 1974)

PROPOSED DATA FOR PROTOTYPE DESIGN REVIEW

In addition to the specified articles to be reviewed at the Prototype Design Review, the following tasks are recommended as subjects for additional discussion.

1. Thermal/cost trade-off studies for the alternate exchanger elements
2. Low pressure fluid valve design
3. Module durability evaluation
4. Module outer shell design
5. Corrosion test results

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